The Water Wealth of Canada: with Special Reference to the Ottawa River Basin

AN ADDRESS DELIVERED BY CHARLES R. COUTLEE, C.E., BEFORE THE FIRST ANNUAL MEETING OF THE COMMISSION OF CONSERVATION

Reprinted from the First Annual Report of
The Commission of Conservation, 1910

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The only source of water, no matter where we find it, whether coursing down in rivers or rising from the soil in springs, is the rainfall. This rain, flowing in rivulets on the surface or seeping through the ground, eventually reaches a creek, a swamp, or a lake, thus collecting to form a flowing river.

There are four uses of water to mankind. First and foremost, drinking water is an absolute essential to life, and this constitutes a first call upon all our sources of supply. Secondly, if the rainfall is not sufficient, plant life is possible only by means of irrigation. Irrigation, however, not only furnishes moisture, but the water conducted to the soil contains silt and mineral salts which renew the land. This is well shown in the Nile valley, where the overflow, covering the ground with silt and mineral salts, has made it possible to raise unrotated crops for thousands of years. This phase of irrigation is often forgotten, but, when more intensive methods of cultivation are adopted, many streams in the well-watered provinces of the east may yet be turned on to the land for the sole purpose of fertilizing it. In the third place, transportation necessitates an assured depth of water in our streams, and, to this end, it is necessary to conserve the rainfall in swamps, lakes or artificial reservoirs, so that low water in the autumn will not prevent a continuous service. The use of water for power purposes is the last charge upon the supply. It is a remunerative business, and so the production of energy adjacent to centres of population has been seized upon by capital which, if not controlled, would demand the whole flow for this purpose [illegible]

Under these four heads of usefulness each of the five [illegible] of Canada will be discussed, that is, under a geographical ar[illegible] we will consider the principal rivers in their relationship to [illegible] lation. This practically means the relationship of water to [illegible] in a particular district.

Pacific Coast—Beginning on the Pacific, the rugged coast-strip [illegible] extends 50 to 100 miles inland from the ocean and rises in that [illegible] distance to a general elevation of 8,000 feet, serves to condense [illegible]

moisture-laden wind of the Pacific, the result being that the rainfall attains the extraordinary amount of 100 to 150 inches per year. The high peaks condense the moisture directly into snow, which, constantly gathering, creates a pressure sufficient in the presence of a very moist atmosphere to harden into ice which gradually moves down the mountain valleys as glaciers. These glaciers as they reach lower elevations melt into water, so that the frozen masses represent reservoirs from which the streams are fed until late in the autumn. Although the lake-basins, or natural reservoirs, are small, still these glaciers and the heavy rainfall give a fairly constant supply for domestic and other purposes.

DOMESTIC SUPPLY OF VANCOUVER—The site of the present city was a forest in 1885. Since it was surrounded by salt water, a source of supply was selected on Capilano creek, where a pond was created by a wooden dam. The water is led down through steel pipes and carried by a submerged conduit beneath the inlet and into the Stanley Park reservoir, from which it is distributed by gravity.

DOMESTIC SUPPLY OF NEW WESTMINSTER—This city is situated on the lower reaches of the Fraser river. As the tide extends up this river, the water is brackish and unfit for domestic use. It was therefore necessary to obtain a supply inland, and a gravity system was installed.

This indicates that, even in the newer districts, the large Canadian centres of population are well supplied with water for drinking and for fire protection. The increasing and, in many cases, unrestrained contamination of streams under the conditions of rapid growth in our population indicates a necessity for central supervision of at least those rivers whose waters wash alternately the shores of different provinces. By authoritative investigation of matters relating to river pollution, the public will be led to understand that our magnificent Canadian streams should not be polluted by allowing sewage or factory wastes to enter without adequate purification.

The relation between pure and ample water supply at all seasons, and the public health, is a question of paramount importance. The ignorance of the public regarding sanitary matters and the laws governing the right to consume water from lakes, streams or springs, and the right to dispose of drainage into the same, prevents effective protest against pollution. Central control founded on technical examination, instead of adjustment through the courts, will give assurance to municipalities as to the future conditions of our streams, and, even with growth of population, the dangers will diminish rather

than increase. Life will be protected, litigation will be avoided, and the municipalities will stand on firm ground respecting their rights with regard to water supplies and drainage.

Under central auspices, extended inquiry and experiment into problems of water supply, sewage and sewage disposal would secure a fund of valuable data from which local authorities would derive benefit, and the public would understand and demand the blessings of modern sanitary research. A correct moulding of the popular mind, founded on a study of local conditions, is much to be preferred to the intermittent and unintelligent enforcement of general legislation. Annual reports, or, preferably, occasional bulletins describing the conditions of water supplies, sewers and disposal systems and projects would build up a sentiment to have and to hold our heritage of water, pure.

The studies required would be systematic examinations of the drainage areas of our principal rivers as to existing or probable pollution from towns, summer residences or manufactories. Physical, chemical and biological tests at regular intervals would determine the relative purity at different points. The determination of discharge quantities for various river basins would be of service in studying the economic possibilities of streams for future power development. It would also serve to prevent the encroachments of private dams, bridge piers, etc., upon the natural flow area—a fruitful cause of floods.

The disposal of sewage and trade wastes is now demanding a great deal of attention from scientists. The capability of a river to purify itself and the necessity of demanding a more or less perfect degree of purity in drainage entering the streams, are subjects that will engage the best scientific thought of the immediate future.

IRRIGATION.—Although the rainfall is very plentiful on Vancouver Island, yet there are portions of the island which require irrigation because the moisture-laden clouds drift over to condense against the Coast range. The irrigation systems, however, are small and generally consist of creeks led on to individual ranches.

Along the coast of the mainland very little irrigation is practised, although the months of July and August are sometimes very dry, and the gravelly soil does not long retain the moisture of the wet months. The islands in the Fraser delta and lower Fraser are protected from the sea by dikes. When the dikes are overtopped by the high water, the result, of course, is a refertilization which is a most important feature of all irrigation.

INLAND NAVIGATION—The rivers fall down steep mountain slopes and are generally too rapid for any kind of navigation, but the deep

inlets along the coast afford access by boat to many points quite inland. It is possible to navigate the Fraser up to New Westminster with sea-going vessels, and above that there are a few stern-wheel steamboats. The Skeena is a large river with many rapids, but has been navigated for 150 miles to Hazelton.

POWER—There is plenty of coal on Vancouver island and on the mainland also, but, owing to the high price of this fuel, water-power was early sought after. About 1903, the Vancouver Power Company developed a site on the shore of Burrard inlet, 18 miles north of Vancouver. Coquitlam lake is joined by a two-and-a-half-mile tunnel to Buntzen lake, thence through wood-stave pipe, to the plant, 400 feet below. Although the drainage area is only about 200 square miles, yet the excessive rainfall is sufficient to maintain 22,000 H.P. This is transmitted to Vancouver, New Westminster and the Delta, supplying over 100,000 people with light, operating electric roads, etc. The transmission line crosses Burrard inlet by a single span over half a mile in length.

Another station will soon be completed at Stave lake, 35 miles from Vancouver. The drainage area is only 360 square miles, but the rainfall of over 100 inches per year ensures 25,000 H.P., the head being 90 feet. The great rainfall and high heads are, of course, most remarkable conditions.

Central British Columbia—In this area the mountains are separated by four parallel north-and-south valleys, viz., the Fraser, 400 miles long, fairly straight and almost north and south; the Okanagan valley, with Okanagan lake nearly 80 miles long; Columbia river and its lake-expansions, the Arrow lakes, extending 200 miles north and south; and the Kootenay valley parallel to, and a few miles west of, the Rockies.

The Coast range intercepts a large part of the moisture from the Pacific, so that the Fraser and Okanagan valleys are semi-arid, but the Columbia and Kootenay valleys have an ample rainfall and snowfall.

Applying our division of uses to the Fraser river, we find that it furnishes, so far, no domestic water supply. The banks are usually steep and rocky, or else high gravel slopes, which are without arable areas or towns of importance. Owing to the salmon pack, it is a question if the river can ever furnish potable water. The fluctuation of the surface is 50 feet, and the great floods carry quantities of silt which also militates against its use for household purposes. The lower reach

of the Fraser, however, from Yale to the coast, is alluvial, but is exposed to extensive floods. Irrigation is practised only at a few points, so far.

POWER—There are great falls along the Fraser, with rocky cañon sides, where power might be developed by the use of rock-fill dams if the river could ever be regulated to obviate the extreme conditions of high and low water. The Thompson river, however, which enters the Fraser at Lytton, furnishes a domestic supply for the town of Kamloops, which is pumped by a vertical engine set over a well. Its tributary, the Bonaparte river, supplies irrigation systems near Ashcroft. Two large reservoirs, Adams and Shuswap lakes, modify the flow of the Thompson somewhat and offer sites for power development.

OKANAGAN VALLEY—Irrigation is practised throughout the valley, where fruits of all kinds have been cultivated with great success. Navigation by stern-wheel steamboat is, so far, the means of communication in the valley, which is reached by railway only at its north end. Power has not been developed to any great extent and no large developments are to be expected, but the fertility of the valley and its fine climate will attract a class of people who will become great users of power.

COLUMBIA AND KOOTENAY VALLEYS—There are four towns in this basin. Revelstoke, on the Columbia, obtains a water supply, not from the river itself, but from the Illecillewaet, which joins the main river at that point. Irrigation is not practised in the Columbia valley to any great extent.

Navigation on the Columbia is, so far as Canada is concerned, confined to the stern-wheel steamers on the Arrow lakes and on the river above Golden. Navigation on the Kootenay river is broken between Nelson and its confluence with the Columbia at West Robson, but is resumed between Nelson and Kootenay Landing.

On the Kootenay river, power has been developed by a very modern plant at Bonnington Falls near Nelson. The head varies from 55 to 65 feet, for, during high water, the flow becomes obstructed by the narrows below the falls. The flow is 6,000 c.f.s. from a drainage area of 10,000 square miles that possesses several glaciers. Eventually 25,000 H.P. will be developed, but only one half is being developed and sold, at present, to Phœnix, Grand Forks, Greenwood, Rossland and Trail, for mine haulage and hoisting, pumping, air com-

pression, and for lighting and municipal purposes. The city of Nelson operates a municipal plant on the opposite side of the river.

Mackenzie Basin—The drainage area of this basin is nearly 700,000 square miles. The Athabaska and Peace rivers unite to form the great Mackenzie, which presents a few power possibilities, although it flows to the Arctic in an almost even grade. They, however, admit of navigation, with interruptions at Grand rapids and at Fort Smith rapids, from Athabaska Landing to the Arctic, a distance equivalent to that from Winnipeg to Halifax. An idea of the coming development of this great basin may be had from the fact that a flour mill has, for years, been operated on the Peace.

The prairie rivers of Manitoba, Saskatchewan and Alberta drain nearly a million miles of territory—that is, twice the drainage area of the St. Lawrence—through two outlets, the Nelson and the Mackenzie rivers. It is rather a fortunate circumstance that the precipitation is not as great as that in the east, and that the area is not covered with a dense timber, because it would prevent a gradual melting of the snow by the sun during March and early April, and would cause the whole flood of melted snow and spring rains to pour down together during the latter days of April.

Lake Winnipeg Basin—It is not generally appreciated that lake Winnipeg is the size of lake Erie, that is, nearly 10,000 square miles in area. The basin that drains into this lake is 350,000 square miles in extent, or nearly the size of France and Spain, which two countries support a population of 58,000,000. The Saskatchewan river, which drains 158,800 square miles of this area, extends west to the mountains and from Edmonton to the 49th parallel. The mountain streams constituting the sources of this great river are very numerous. Many of them are fed by glaciers and offer a continuity of flow that promises well for water-power when an increasing population provides the demand.

The next great tributary of lake Winnipeg is the Red river, rising in Minnesota and flowing north to Winnipeg, where it is joined by the Assiniboine. From there it continues through the St. Andrews rapid to the lake. Both the Red and the Assiniboine, like the Saskatchewan, are alluvial rivers worn deep down in the prairie soil to an almost even grade, and are, in general, without the valuable falls over rocky ledges that so easily lend themselves to power development. Their swift running floods and ever changing shoals are a great detriment to navigation, especially on up-stream trips. As there are no lakes along these rivers, the spring thaws and early rains

sweep down unrestrained by swamps and ungathered by reservoirs, so that their beneficial uses are largely lost to the communities along the river banks.

The prairie river generally occupies the bottom of a great depression a mile or more in width, with steep sides 100 to 200 feet in height, which are deeply furrowed by gulches of accessory streams, creeks and rivulets that are generally dry in summer. The main stream meanders through the bottom land, and during great floods, the minor banks are overtopped and the bottom of the valley flooded.

The prairie lakes are often of considerable area, 40 square miles or more, but are generally shallow. The sloughs are filled with a fair depth of water during wet years. They have no outlet streams, but in midsummer they shrink to insignificant ponds. This decrease in volume renders them very alkaline. These peculiar conditions of the prairie water supply can be understood by giving examples of the methods employed or projected to make the most of them.

DOMESTIC USE—Edmonton, the capital of Alberta, derives a water supply from the Saskatchewan. Calgary has a water supply owned by a private company and drawn from the Bow river. A pile dam has been made across the entire river, and a wooden flume along one shore leads the water about half a mile to the wheels. The population is now over 20,000, principally located upon a flat about forty feet above the river. Residences are now being built upon the surrounding plateau, 200 feet higher, so power for pumping must soon be increased. The coal mines at Canmore and Banff are only 80 miles distant by rail. Medicine Hat pumps its supply from the South Saskatchewan. The power used is natural gas, of which the locality has a plentiful supply. Increase of population at Calgary, Macleod and Lethbridge will bring up the question of sewage contamination at Medicine Hat, which is down stream from all these places. The same difficulty, too, will arise, later, at Saskatoon and Prince Albert. Regina is at present supplied from Wascana creek. Later, it may be necessary to utilize Last Mountain lake. Brandon takes its supply from the Assiniboine, which also furnishes the power for pumping. Winnipeg, the third largest city in Canada, obtains water from a system of artesian wells. The pumping was formerly done by steam, but the high price of coal has led to the adoption of electric power generated on the Winnipeg river.

IRRIGATION—Two extensive irrigation schemes are now in operation. One near Lethbridge, takes water from the St. Mary river, the main canal being led along side hills and into sloughs which act as reservoirs.

The system was begun in 1897, and very good results have been obtained from land that, without water, would have yielded very uncertain crops, although, during wet years, there is sufficient rainfall for general farming. Calgary has become the centre of a large system built and operated by the Canadian Pacific railway. This Company received the final allotment of its land grant in one block near Calgary. In 1903, a main canal 100 feet wide, was begun, and now carries water from the Bow river by branch ditches, to serve 1,000,000 acres. Further extensions are proposed for the near future.

Because the prairie rivers have cut so deeply into the soil, they do not lend themselves easily to the irrigation of the general prairie level. Their swift current, however, points to a method of pumping up the water, and as the amount required is very moderate, only 1 c.f.s. being necessary for 100 acres of land, the systems of pumping need not be elaborate. In Washington state, the current of Snake river is utilized in the following manner. A long, narrow raft is anchored in the stream; each end is furnished with rollers and an endless belt with wooden vanes or paddles is revolved over these rollers by the current into which the paddles dip on the under side of the raft, the upper paddles returning in air. The power thus generated runs a Jacobs-ladder pump that lifts the water up to a trough, through which it is led to the land. Another method of obtaining power from a river current is by a series of screw propeller wheels mounted on a shaft which is held beneath a float in the direction of the current. Windmills are also frequently used, and the winds are generally fairly constant over the area in question.

Navigation—A boat, launched in the Red river, sailed down to lake Winnipeg and through it to the mouth of the Saskatchewan, thence it was hauled and poled up the Grand rapids to Cedar lake, whence it proceeded to Edmonton. This boat was used during the rebellion of '85, and finally went to pieces against the piers of the Edmonton bridge. This gives some idea of the immense stretch of navigable waters through our prairies, but, owing to the swift current, the economy of such transportation is not quite assured. If a large quantity of heavy raw material like coal or iron ore were offered for through transportation, then a system of cheap barges pushed in front of a stern-wheel steamer might be used. Such barge rafts carry coal down the Ohio and Mississippi to New Orleans, where the barges are broken up and sold as lumber.

On lake Winnipeg there is considerable navigation, largely connected with the fish industries. The new lock at St. Andrews rapid, when completed, will extend navigation to Winnipeg and above.

Although the Saskatchewan is subject to extreme freshets, yet piers for bridges have been built in the river at many places and have withstood for years the force of its floods. It is, therefore, reasonable to expect that a dam consisting of high piers upon a heavy floor of concrete extending across the bottom of the river, could be economically built. Between these piers, steel curtains, forming the actual dam, could be raised vertically during freshets, permitting the flood water to pass unimpeded. As the flood decreases the curtain would be gradually lowered into the water so as to keep the upper level at a fixed height, while the natural flow of the river passed between the lower edge of the curtains and the concrete floor. Such constructions would regulate the river into convenient steps, or reaches, each of which would form a conservation reservoir that would save for summer use the valuable water supply of the prairies that is now dissipated in spring floods. Water held at a high and constant level is always a most valuable asset to any community.

POWER.—At present the prairie rivers furnish very little power, although their tributaries in the mountains are already being exploited for use at Calgary and other points. Coal is cheap and abundant in the western section, but further east, with increasing population, cheap power will be in demand, and the moveable dams above described may yet be tried. Lake Winnipeg is an enormous reservoir 700 feet above Hudson bay. It flows out through the Nelson river, which tumbles over many rocky ridges, giving exceptional opportunities for water-power.

A great rock outcrop along the west side of lake Winnipeg separates it from lake Winnipegosis and Dauphin lake, which are 100 feet higher. This outcrop also crosses the mouth of the Saskatchewan, creating the Grand rapids, with a fall of 71 feet, 250 miles north of Winnipeg.

There is, however, a third great tributary of lake Winnipeg, the Winnipeg river, which has a drainage area the same size as the Ottawa, 55,000 square miles, or the size of England and Wales. It also runs through a similar gneissic rock territory. Its upward extension is Rainy river, forming the boundary between Canada and the United States, and emptying into the lake of the Woods. The Winnipeg river flows out of this lake over tw[illegible]s, giving exceptional opportunities for power. Near Kenora 5,0[illegible].P. is generated and used for flour milling and for municipal purposes. The head is 18 feet, and a remarkable dam of loose rock thrown into the bed of the river maintains the elevation of the lake; the river flow, 15,000 c.f.s., is passed through stop-

log sluices. Farther down the river, and 75 miles from Winnipeg, is Pointe des Bois, where the city of Winnipeg is building a municipal power station with 46 ft. head. Here, another rock-fill dam has been built.

Farther down, the river branches into two channels, and upon the Pinawa channel a power with 35 to 40 feet head is operated by the Winnipeg Street Railway Company for street railway and other purposes.

St. Lawrence Basin—The watershed area is 550,000 miles, one-sixth of which is the water system of the Great lakes, which constitutes the most remarkable reservoir system in the world. The north coast of lake Superior is rocky and sparsely peopled; consequently, apart from the demands made upon it by Fort William, Port Arthur, and Sault Ste. Marie, lake Superior is but little drawn upon for domestic supplies. The drainage of Fort William and Port Arthur discharges into the lake.

The western portion of Ontario contains numerous flourishing towns. The two chief rivers are: the Thames, flowing through London and Chatham, the latter of which derives its supply from its waters, and the Grand, which furnishes the supply for Brantford. Toronto pumps its supply from lake Ontario, the water being carried beneath the harbour through a tunnel. The drainage has been deposited without treatment in the lake, but plans are now under way to instal a large filtration plant. This cannot be too highly praised, for, although lake Ontario is too large, and the flow is too great, to admit of gross contamination, still wind storms constantly tend to drive pollution ashore, whence it is liable to be carried by flies and other agencies to the inhabitants of the city, or, what is the same thing, to the farms whence their milk supply is derived. Port Hope, Cobourg, and Kingston derive domestic supplies from the lake also, and, unfortunately, drain into it.

Montreal has, for 50 years, obtained water from above the Lachine rapids. It was conducted through an open canal to the pumping station, whence it was raised to the reservoirs upon the mountain. Lately, however, closed concrete conduits have taken the place of the open canal. Much has been said regarding the use of this raw water, and there are chances of dangerous pollution from a dense population, but, a much more pressing question is whether this great city should be allowed to pour its drainage into the river. We are inclined to expend enormous sums to get good water, but it is far more important to be certain that this water supply is returned to the river in an unpoisoned condition. People have been accustomed to make money by supplying water; therefore, they seem to see no gain in proper drainage, simply because it gives no direct money returns.

The great tributary of the St. Lawrence, the Ottawa river furnishes domestic supplies to various towns from New Liskeard to Montreal, a distance of 400 miles. Haileybury and New Liskeard pump by steam from lake Timiskaming; Pembroke pumps by steam from Allumette lake; Ottawa has its supply led through two miles of steel pipes laid in the bottom of the river and pumped direct throughout the city by water-power.

IRRIGATION—Notwithstanding the fact that the farm districts of Ontario and Quebec suffer annually, from drought during the summer, yet no attempt is made to irrigate, although many suitable creeks are to be found. This is remarkable because the whole population is accustomed to building small dams for lumbering and milling purposes and also to digging ditches for drainage purposes. It is a natural step to conduct water in ditches from a dam above, for use as a fertilizer, as well as for a source of moisture.

DRAINAGE—If the people of central Canada do not resort to irrigation, they undertake extensive drainage schemes. Kent and Essex counties in Ontario are remarkable in this regard, and other districts are constantly extending the area of tillable land. This is beginning to have an effect upon the rivers. Swamps are reservoirs, just as lakes are reservoirs, in which the upland drainage is collected to seep slowly through the muck and earth toward streams and rivers. When the drainage is led past these valuable reservoirs by free flow in ditches, it sweeps forward without restraint, and the rivers receive a great bulk of water in a short time, causing the annual floods that scourge many districts. Again, of the water that falls from the clouds, 50% is "fly-off," or evaporation, 33% is "run-off," or stream flow, and the remainder, 17%, is "cut-off," or stored in the ground. This ground storage serves to keep the land moist and also to maintain the stream flow during the late summer until the autumn rains restore the supply. It will be seen, therefore, what an important part the swamps play in the regulation of our streams, and I submit that they should be jealously guarded as reservoirs and as forest reserves throughout the whole Dominion.

NAVIGATION—The Great lakes and the St. Lawrence afford the greatest inland navigation route in the world. Jacques Cartier and Champlain could reach Montreal only in row boats, but, since 1850, an immense amount of dredging has been done in the St. Lawrence, so that, to-day, ocean liners of 30 feet draft freely ascend to Montreal. West of Montreal, a great system of canals has been con-

structed at a cost of $80,000,000, so that a 2,200 ton boat can sail from the Atlantic 2,200 miles into the heart of our Continent. This great enlargement of the actual river has, of course, improved the freedom of its flow and therefore tends to somewhat lower the general water surface from Superior to Quebec. With the increasing size and draught of boats upon the Great lakes, this lowering of the surface is making itself felt, especially in lake Erie. To maintain a navigable depth it is proposed to build a dam across the Niagara river above the Black Rock bridge. The proposition is fraught with difficulties. Storms from the south-west "pile" the water of lake Erie toward the Niagara outlet, and this "pile" upon the already raised surface will flood valuable property. Again, as part of the natural flow is arrested and held upon lake Erie, lake Ontario does not receive as great a supply, and its surface would tend to fall, unless, in turn its outlet were also dammed; and so on down the river through lake St. Francis to the head of Montreal harbour, where the loss of every inch in height necessitates expensive dredging to ensure, in the autumn, sufficient depth for ocean-going vessels. It is hoped however, that a general system of raised levels throughout the St. Lawrence will yet be secured.

POWER—The St. Lawrence system, having the most densely settled communities along its banks, has been called upon to furnish power for manufacturing and municipal needs. Fort William and Port Arthur on lake Superior derive power from the Kaministikwia river at the Kakabeka falls, 19 miles distant, where a head of 175 feet generates 7,000 H.P. Sault Ste. Marie depends upon water-power for its existence. The head is only 18 feet, but the discharge is 60,000 c.f.s. and very constant. Pulp mills, a steel plant and municipal utilities are the chief users of the power. Nipigon river just below Fort William, offers great power, which will be developed when a market presents itself. Sudbury is the centre of a mining district which has received power from the Spanish river at Turbine since 1904. The head is 85 feet. Vermilion river is now furnishing power to other mines in this district. The French river has not been developed, but, as the western link of the Ottawa navigation, it may yet furnish considerable power at the proposed dam sites.

The Severn and other rivers in western Ontario have small local powers, but the great Niagara developments completely overshadow anything else in the district. Unfortunately, only half the descent between lakes Erie and Ontario has, so far, been utilized, except in the case of the Cataract Power Company, where the head is 270 feet. The

Trent river, flowing diagonally through Ontario to the bay of Quinte, has several powers developed, and the dressing up of the river for navigation purposes may lead to further installations. Below Prescott, the St. Lawrence river plunges through a series of rapids, falling 100 feet in 30 miles. The sloping surface does not lend itself as readily to power purposes as an abrupt fall, and the rapid water creates ice difficulties. Consequently, nothing has been done so far, but a company is now seeking permission to build a dam and power house in the vicinity of Cornwall.

From Coteau, at the foot of lake St. Francis, to the head of lake St. Louis, 20 miles above Montreal, the St. Lawrence falls over 80 feet in 15 miles, but the same difficulties present themselves as at Cornwall. Lately, however, a power has been obtained from the Soulanges canal, and another development is proposed at Cedars; while the old Beauharnois canal has been transferred to a company that is constructing a power at St. Timothée. No attempt, however, is being made to completely dam the river, although the numerous islands indicate this to be possible, and a river arranged in successive steps is a most valuable power stream.

Montreal has had a hydraulic pumping system since 1854, but not until 1897 was an attempt made to procure power from the great Lachine rapids. Only 14 feet head was secured, and great trouble was experienced from ice. It is an example of the waste incurred by partial development. The rapid water above Montreal prohibits surface ice from Dorval down to Lachine, and large quantities of anchor ice form in this open stretch. This drifts down through the rapids and blocks the whole river in the vicinity of Montreal, so that the water rises and floods the wharves and shores in its endeavour to pass through its ice-gorged channel. If a large rock-fill dam, similar to those used on the Winnipeg river, were constructed across the Lachine rapids, then the surface of lake St. Francis would be produced to Heron island, where sluices and a power house could be constructed, making the whole flow available through a fall of 25 feet. Another dam at St. Helen island would pen up the Laprairie basin 25 feet higher than the harbour, creating another great water-power. As the surface of these ponds would be level and quiet, they would freeze over early in the season, thus preventing the formation of the ice that now causes such havoc in the port of Montreal, and boats would pass up from the harbour through only two locks with great basins between them, instead of through the many locks and narrow channel of the Lachine canal.

Montreal also obtains power from the Shawinigan falls, on the St. Maurice, 85 miles distant, and from the Chambly plant on the Richelieu river, 20 miles distant.

Quebec has three power stations, one each on the Jacques Cartier, the Montmorency and the Chaudière. The tributaries of the St. Lawrence below Quebec present remarkable power possibilities, as they flow in rock basins with many abrupt falls.

New Brunswick—An abundant rainfall, and a snowfall which does not melt until April, fills the lakes and swamps with a store of water that keeps the rivers replenished until the autumn, when the rains augment the flow to some extent and maintain it beneath the snow. The spring melting furnishes a great body of water, most of which, unfortunately, runs away. There are several rivers with exceptional power possibilities, but, so far, only the St. John river has been exploited. The Grand Falls Power Company is building a plant at that place to develop 80,000 H.P. eventually, under a head of 130 feet. This will be used for the manufacture of pulp and for the municipal supplies of Woodstock, Fredericton and St. John, the latter 165 miles distant.

Nova Scotia—The Province is 300 miles long, but only 75 miles wide. It is not to be expected, therefore, that large rivers offering great power would exist. Numerous power plants are furnishing light, but steam plants will probably form the chief source of power in a province whose coal supply is so great and so well distributed.

Domestic Supplies—These are generally taken from the local streams, which are small, but which are maintained in many places by large swamps or mosses. Pumping is generally done by steam power.

Irrigation and Navigation—No irrigation is practised.

Although the coast is navigated from end to end, and many of the rivers' mouths are entered by large tramp steamers, yet the upper reaches are too shallow or too rapid for the use of steamboats.

Power—There are several small power plants for pulp grinding, etc., but electric energy will likely be developed through steam, there being such a plentiful supply of coal.

Ottawa Basin—It has previously been mentioned that the Ottawa river would be treated last. This was because an investigation of its watershed has been made in connection with the navigation scheme, and the knowledge gained has resulted in storage works being com-

menced. The Ottawa watershed is very similar to those of the north slope of the St. Lawrence basin, and a detailed description is of interest because the Ottawa is typical of this class of river

The Ottawa basin is 56,000 square miles in area. Ten thousand of this lies south of the river, and is drained by the Petawawa, Bonnechere, Madawaska, Mississippi, Rideau and South Nation rivers. Five thousand square miles drain into the main stream through insignificant tributaries. Forty thousand square miles lie north of the river. The Dumoine, Black, Coulonge, Gatineau, Lievre and Rouge rivers drain 20,000 square miles of this, and the other 20,000 square miles, which includes the drainage area above Mattawa, forms the upper basin

This upper Ottawa basin contains Grand lake Victoria, with an area of 40 square miles, and Quinze-Expanse, having an area of 100 square miles. The area draining into Grand lake Victoria, 4,500 square miles, contains twenty lakes aggregating 300 square miles of surface and several large rivers, the Kamch ama, Kapitachuan and Shoshokwan. At the outlet of Quinze-Expanse lake the watershed area has increased to 10,000 square miles, and the Kinojevis and Opasatika systems of lakes and rivers have increased the high-water flow from 25,000 c.f.s. to 80,000 c.f.s.

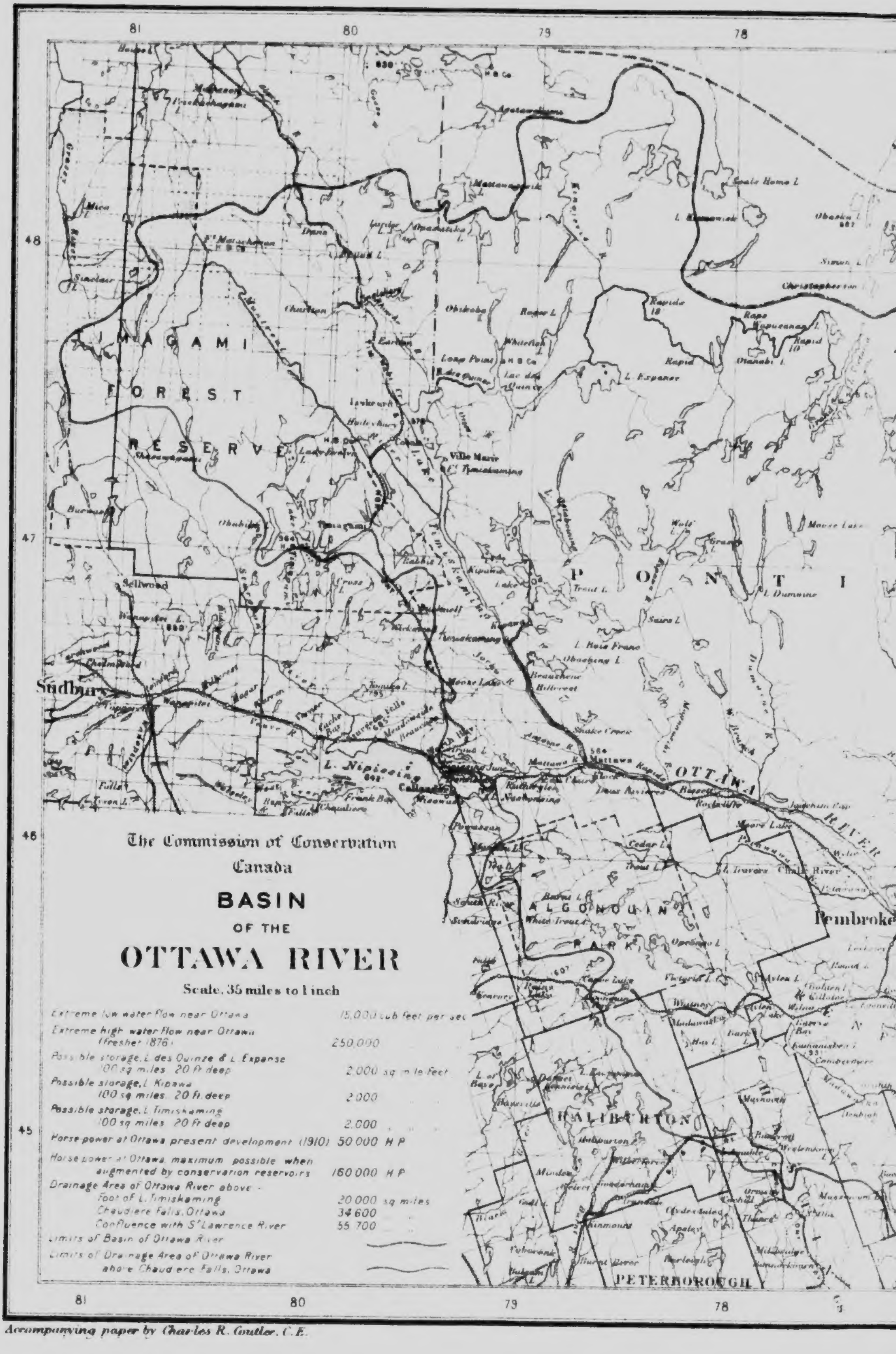
This stream now enters the north end of lake Timiskaming having, in the intervening stretch of 15 miles, descended 300 feet over rocky barriers that present wonderful visions of water-power. All this power has, virtually, been disposed of by lease, for the remainder of this century. Lake Timiskaming extends 60 miles south from New Liskeard to Timiskaming wharf. Between Timiskaming wharf and Mattawa the river is broken by the Long Sault and Mattawa rapids with a fall of 40 feet each. To the west of lake Timiskaming is lake Timagami, part of which flows in *via* the Montreal river, and to the east of Timiskaming is lake Kipawa, draining a territory of 2,300 square miles. The latter has a surface of 100 square miles and is nearly 300 feet higher than Timiskaming. The whole basin is 20,000 sq. miles in area, and the run-off at Mattawa is 110,000 c.f.s. during floods, but dwindles down to about 10,000 c.f.s. or less during the low-water period.

The regimen of a river, that is, the discharge at high water, at low water, and at intermediate stages, is studied by keeping a daily record of its surface at several points—lake expansions if possible—and then metering the flow at high water, medium water and low water. As the lake rises, the discharge increases in a regular ratio, and, as it falls, the discharge diminishes at a similar rate.

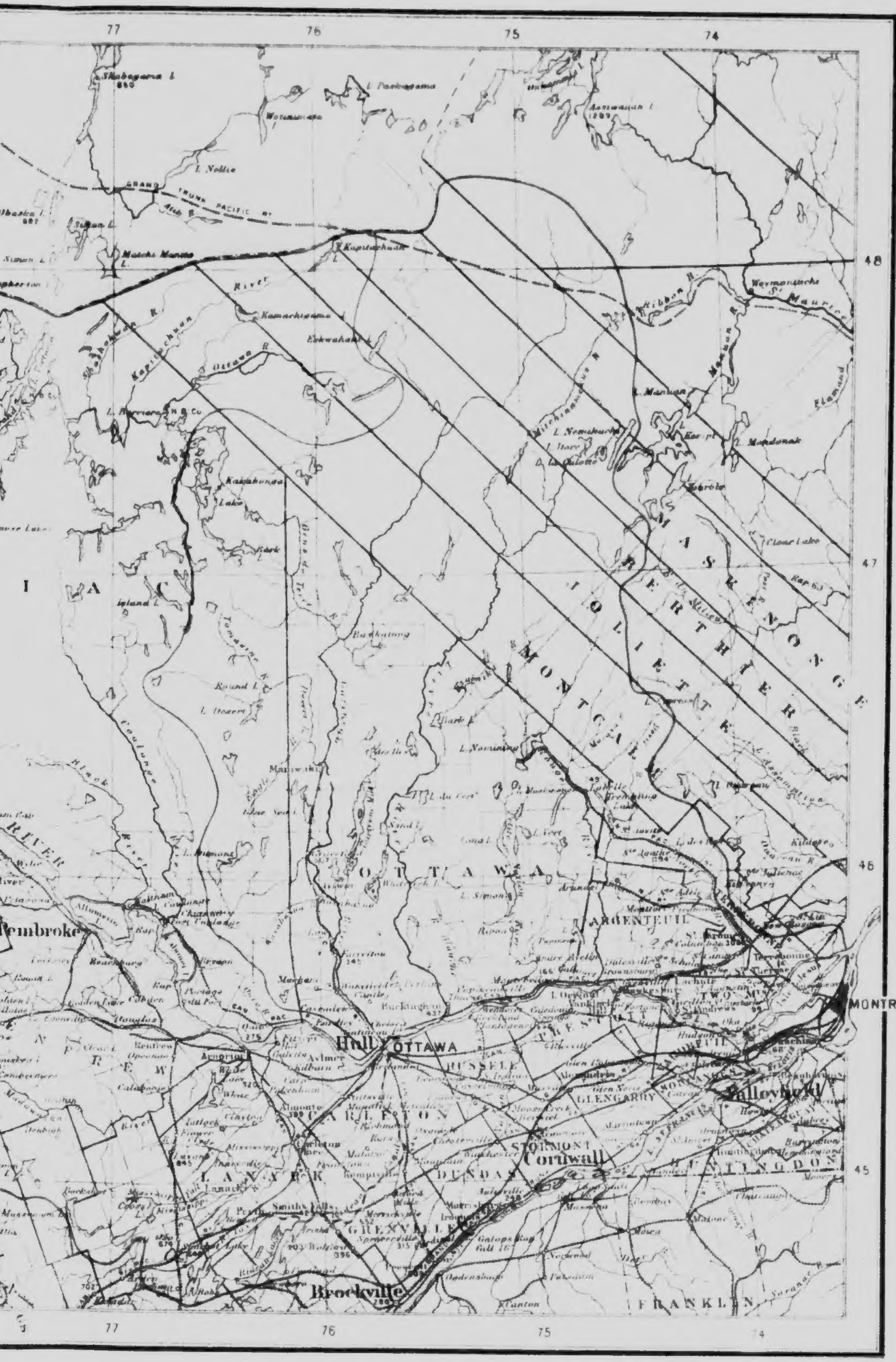
The lockmasters on the Canadian canal systems measure the depth of water on the lock-sills every day in the year. This has been done at Ottawa since 1844, and, owing to this most fortunate circumstance, we can deduce the discharge on each day of the twenty odd thousand days since. I cannot too strongly urge upon all who desire to conserve our water supplies this simple matter of keeping daily gauge readings, winter and summer, for, whenever information is required to develop water-power, to build locks, or to construct reservoir dams, this record is a fundamental requirement.

The record of the Ottawa river has been charted, and, from it, the following general facts have been obtained. The average flow during sixty years has been 55,000 c.f.s., or about 1 c.f.s. for each square mile of watershed. That is, if the main river and all its tributaries had the spring flood conserved in reservoirs, the flow at Besserer Grove would then average 55,000 c.f.s., instead of rising to 250,000 c.f.s. in May, 1876, and shrinking to 10,000 during the winter months of other years.

Diagrams made by the Georgian Bay Canal Survey branch of the Public Works Department show how the flow accumulates *en route* from Mattawa to Montreal during some typical years in the history of the river. The peak of the flood is always reached during the month of May, generally between the 10th and 30th. The flow begins to increase about the 1st of April and falls to normal during July, whence it falls steadily till the succeeding month of April, except for the rise due to the autumn rains during October and November. September shows the lowest water, and January, February and March are always near the danger point for power developments, thus immensely diminishing the value of the river. In fact, during the winter of 1908, it was difficult to get from this great river power enough to carry on the public utilities at Ottawa. This brought affairs to a crisis, and the local power holders came to an agreement to construct a series of stop-log sluices across the Chaudière falls, thereby saving the water that formerly ran to waste, and also creating a head-basin to lessen the ice difficulties. The basin formed, however, is only three square miles in extent, and a draught of 10,000 c.f.s. would lower its surface 10 feet in a day. It was therefore necessary to examine the lake reservoirs along the route with a view to storage. Above Ottawa is Deschenes lake, 45 square miles in area, lac des Chats, 40 square mile in area, Coulonge lake, 25 square miles in area and Pembroke lake, 60 square miles in area, and, above Mattawa, is lake Timiskaming, 115 square miles in area, with Kipawa, 110 square miles in area, and the Quinze-Expanse, 100 square miles in area. Timiskaming, Kipawa, and Quinze-Expanse form a system of reservoirs that can be cheaply con-



Accompanying paper by Charles R. Coutler, C.E.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STORMONT
Cornwall
DUNDAS
GRENVILLE
L A N A R K
Smiths Falls
Brockville
Ogdensburg
FRANKLIN
MONTREAL

trolled. It is greater in extent than all the other lakes in the Ottawa basin put together, and capable, owing to the character of the country, of being raised, not 4 or 5 feet, but 15 or 20 feet.

A stream 100 feet wide and 3 feet deep, running 1 foot per second, or two-thirds of a mile an hour, would fill 1 square mile a foot deep in 24 hours; in other words, 322 c.f.s. will fill or empty a square mile in one day. Now, if a reservoir is 100 square miles in extent and a layer 20 feet in depth is stored on it, there would be 2,000 square mile-feet of storage. This is just about the capacity of each of the three lakes, Timiskaming, Kipawa and Quinze-Expanse, so that, altogether, their storage would amount to 6,000 square miles 1 foot deep. It would take a flow of 18,000 c.f.s. to empty the three reservoirs in 100 days, or a flow of 12,000 c.f.s. to empty them in 150 days—the average low-water period of the river. If we encroach upon the spring flood and allow only a normal flow to pass, these three great reservoirs would be filled up with a reserve supply to be fed out during November, December, January, February and March, and would, thereby, double the present insufficient low-water flow.

This conservation is necessary, not only to augment the winter flow, but also to restrain the flood and prevent unduly strong currents in the navigation scheme. The scheme is, briefly, to dress the river up in convenient reaches by large rock-fill dams provided with sluice openings to pass the flow from basin to basin, locks being provided at each dam. It would be possible to build the dams required at any point as soon as the reservoirs are completed, and offer, in advance of a navigation project, sites for power development with a guaranteed steadiness of flow, and a constant head without ice difficulties.

The river being thus arranged by dams, power would be developed on a general scheme, which could be enlarged to utilize the whole flow at each point in years to come, when transmission may convey to unheard-of distances, and when large blocks of power will be required for heating, for nitrogen fixation, for smelting and for other electro-chemical processes.

The key note of conservation is not only to prevent waste, but also to encourage useful development. Our winters furnish snow, that is, water in the best form for storage, and it is following the trend of nature to create reservoirs for its conservation. The ultimate result will be that the territory from Labrador to Fort William must become a great power centre, and, by improved transmission, distribute power to great distances. Indeed, by the end of the twentieth century, the Ottawa valley may be the power heart of the world and the centre of a delightful district unsullied by coal smoke and beautified by reservoirs of unrivalled natural beauty.